



- I. Overview (30 m)
  - a. Brief history, aerosol exposures
  - b. Equipment/animals
  - c. Class III cabinets
  - d. Procedural video
- II. Aerosol generation (15 m)
  - a. Overview of generation technologies
  - b. Collison nebulizer
  - c. Viability
- III. Sampling & characterization (15 m)
  - a. Methods of sampling (impinger, filter, etc.)
  - b. Particle sizing
  - c. Deposition and retention
- IV. Dose (15 m)
  - a. Definition of dose
  - b. Calculation
  - c. Importance of the 'spray factor'
- BREAK**
- V. Emerging Technology (30 m)
  - a. **Genesis of the automated technology**
  - b. **Application**
- VI. Examples: aerosol exp. of animals (30 m)

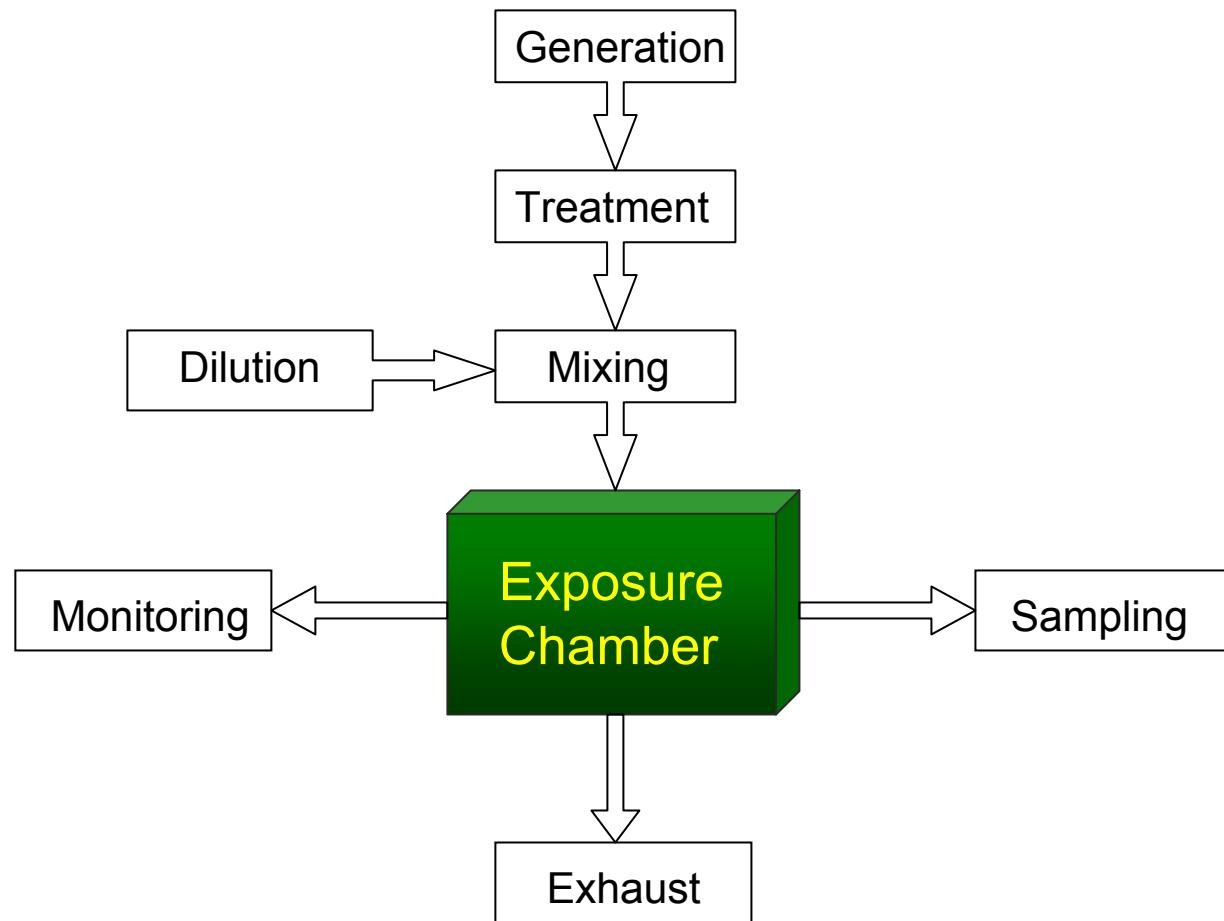


# Development of an Automated Bioaerosol Exposure System

- Motivation
  - Manual control and hybrids of automation
  - Limited data acquisition in existing systems
  - Aerosol work is technically demanding
  - No standardization in aerosol work
- Objectives
  - Computer control of aerosol system
  - Improved control and data acquisition
  - Ease of use - “plug and play”
  - Standardized data recording and archiving
  - Integrate all aerosol functions into one platform
  - Improve dose *control* and dose *calculation*

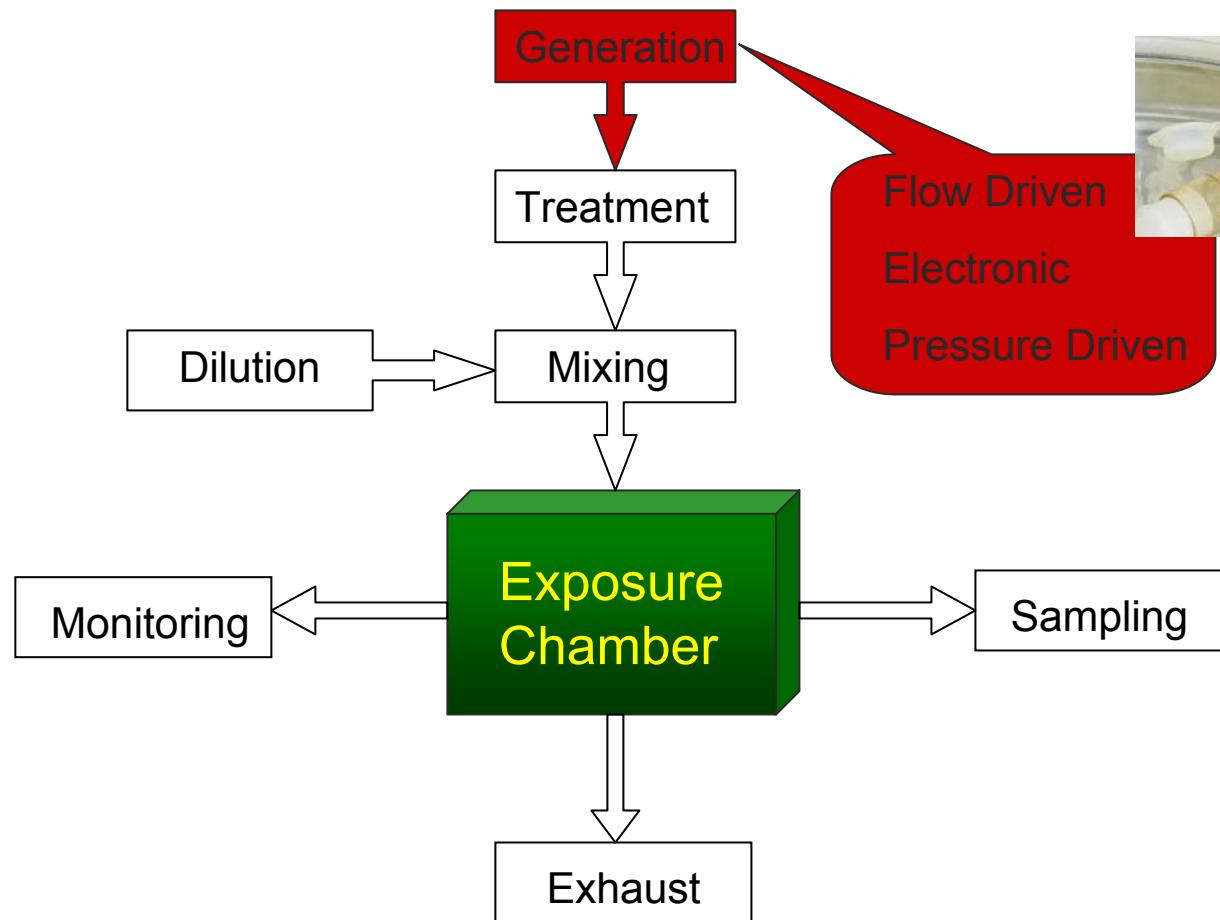


# Dynamic System Components



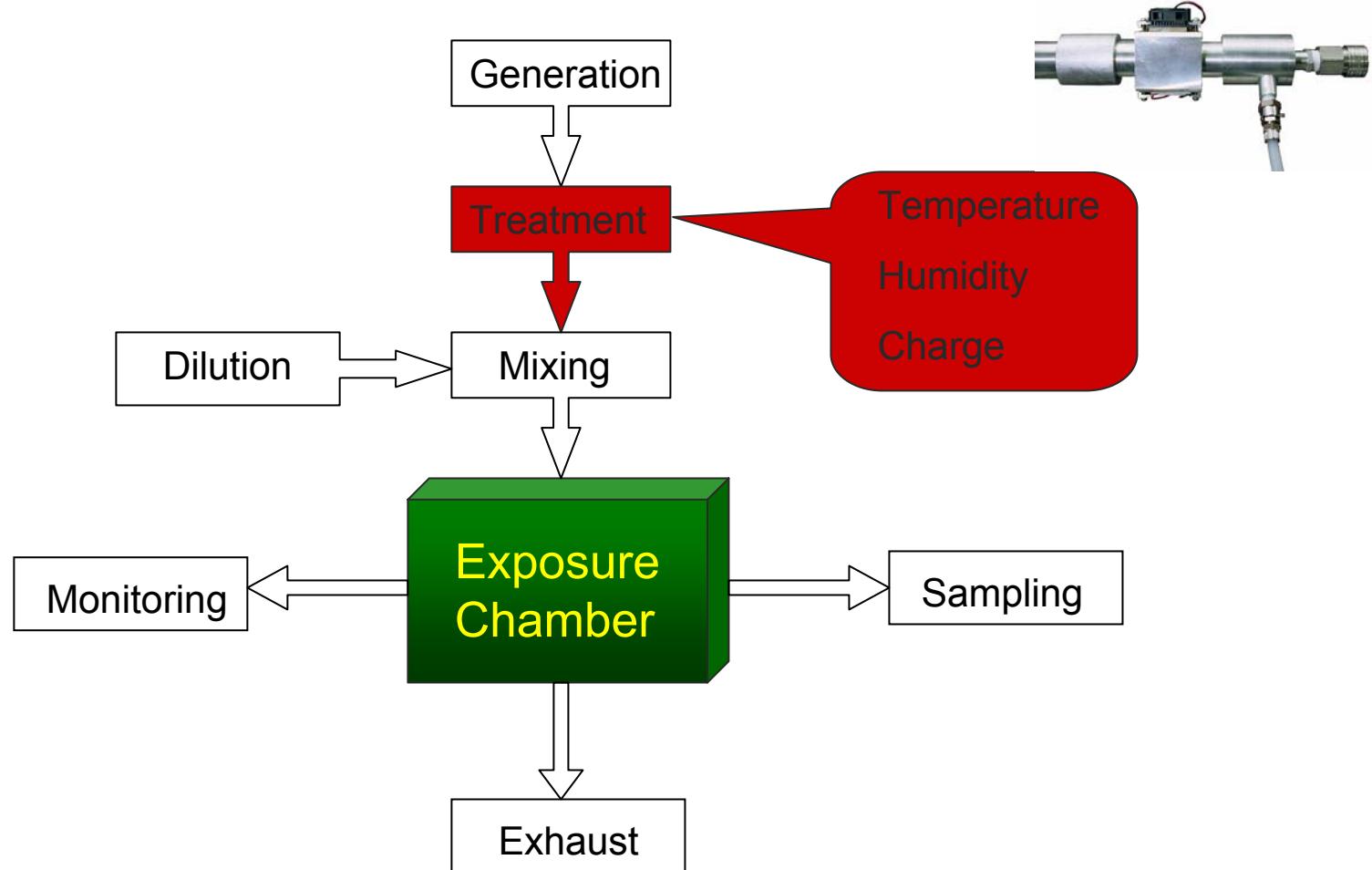


# Aerosol Generation



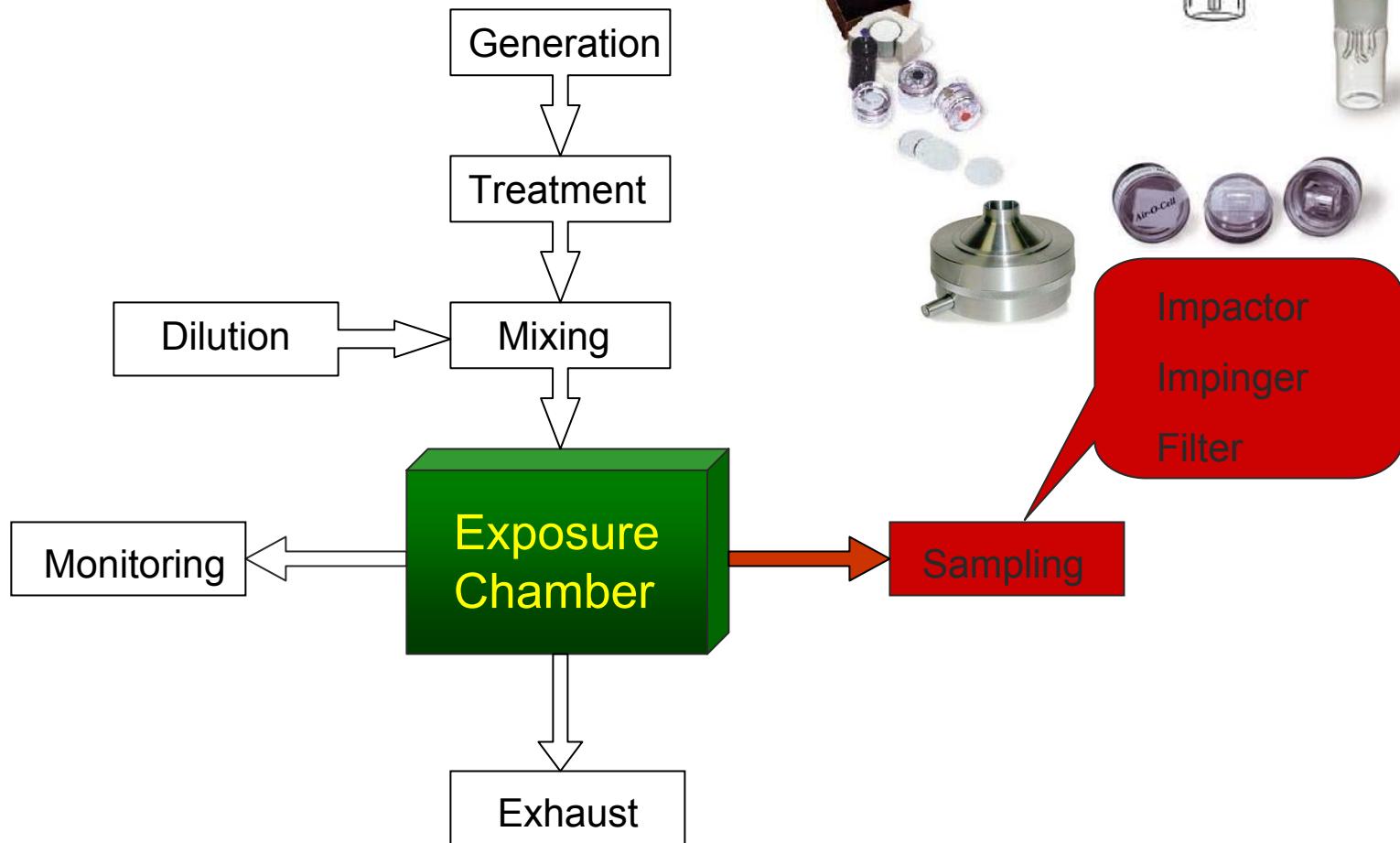


# Aerosol Treatment



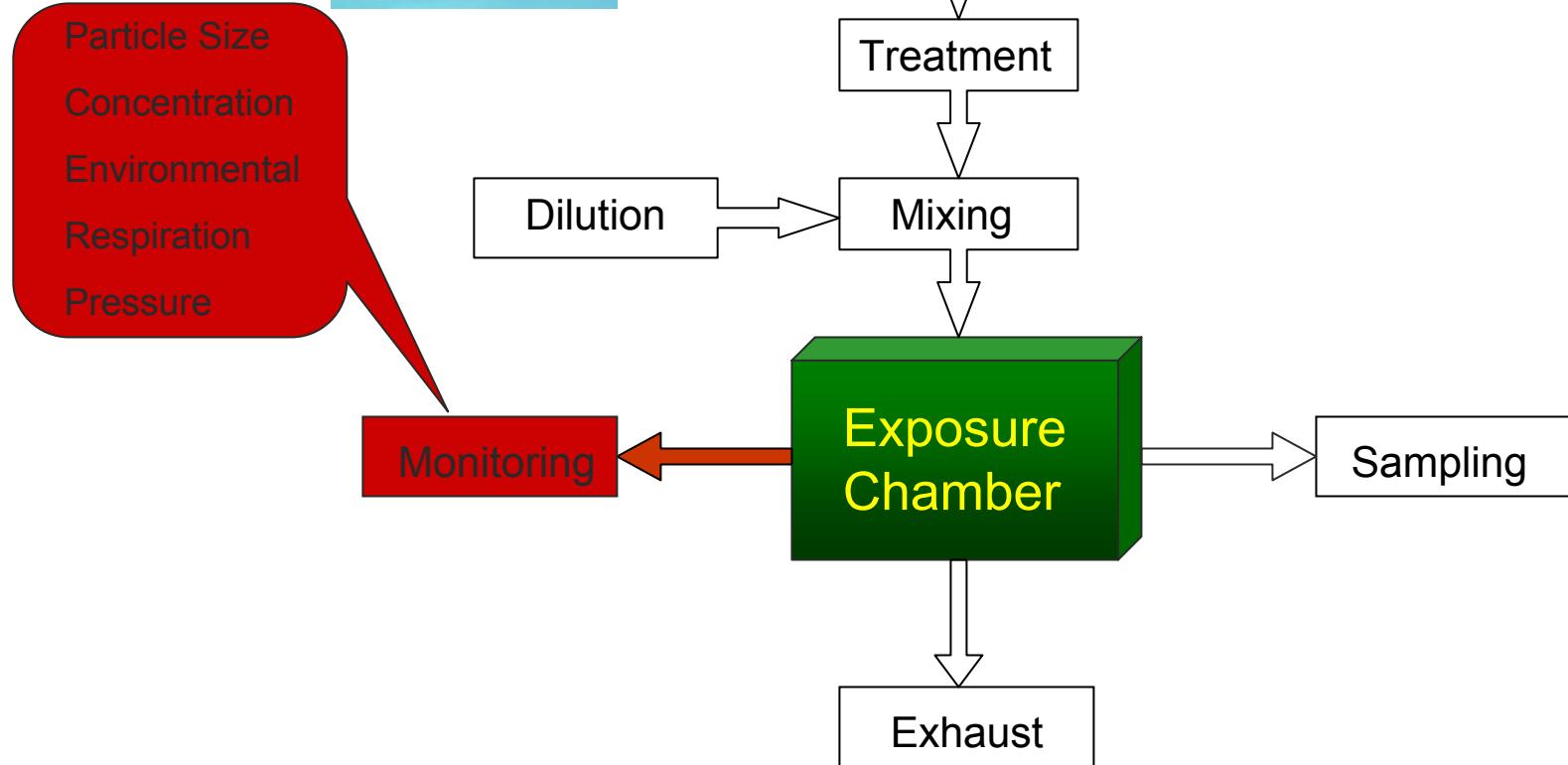


# Aerosol Sampling



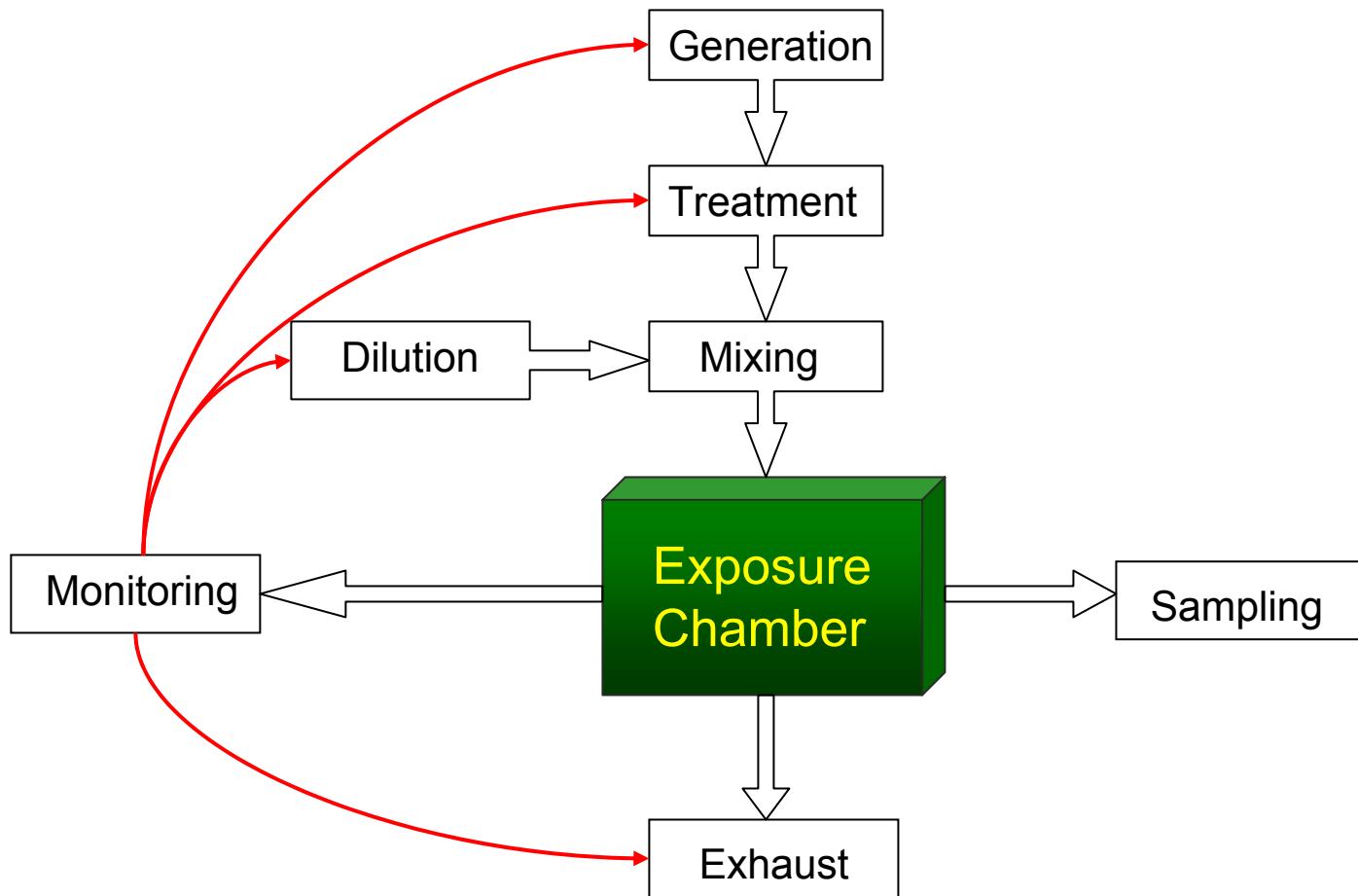


# Aerosol Monitoring





# Feedback

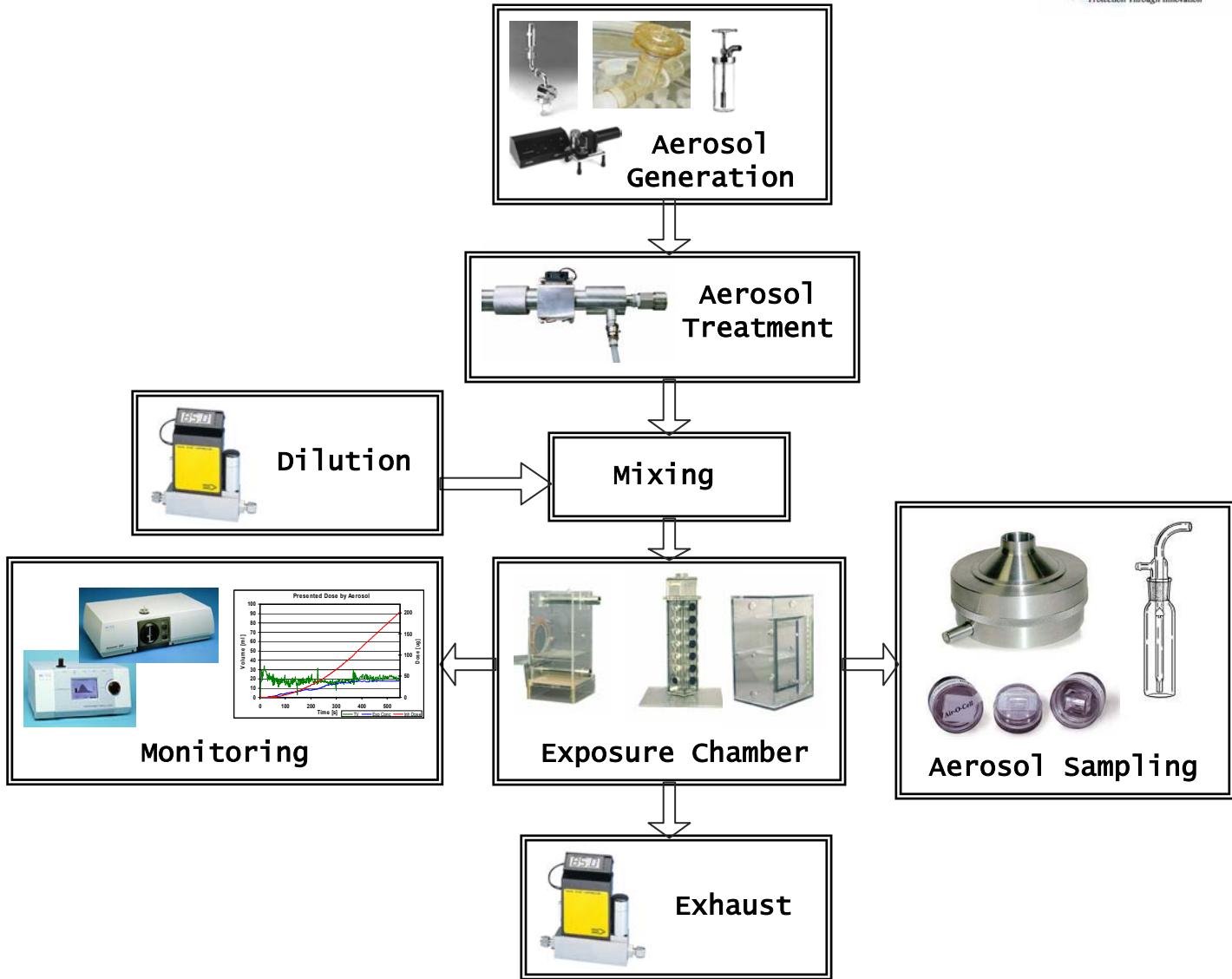




# Aerosol Management Platform Concept and Operation



Aerosol  
Management  
Platform

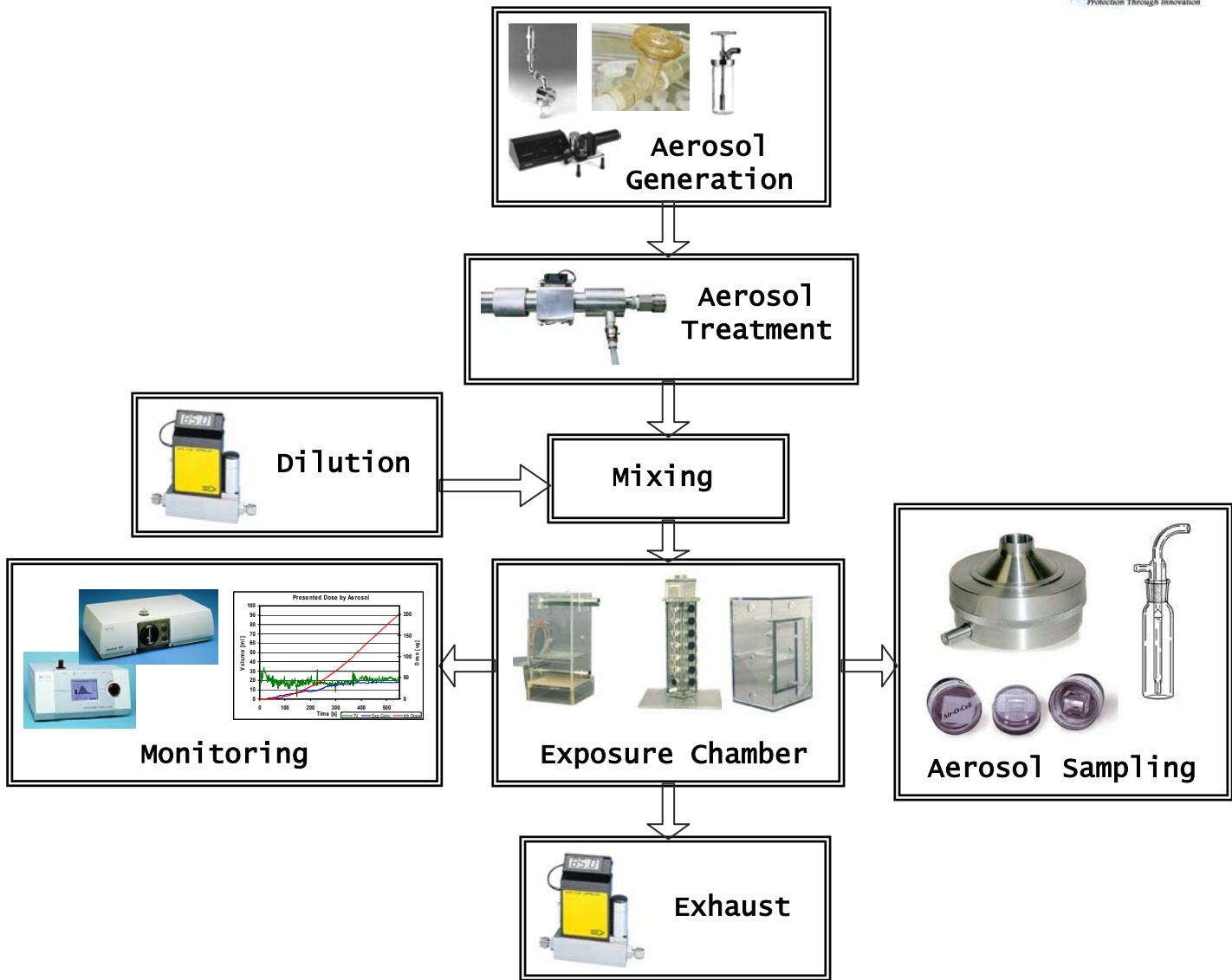




# Aerosol Management Platform Concept and Operation

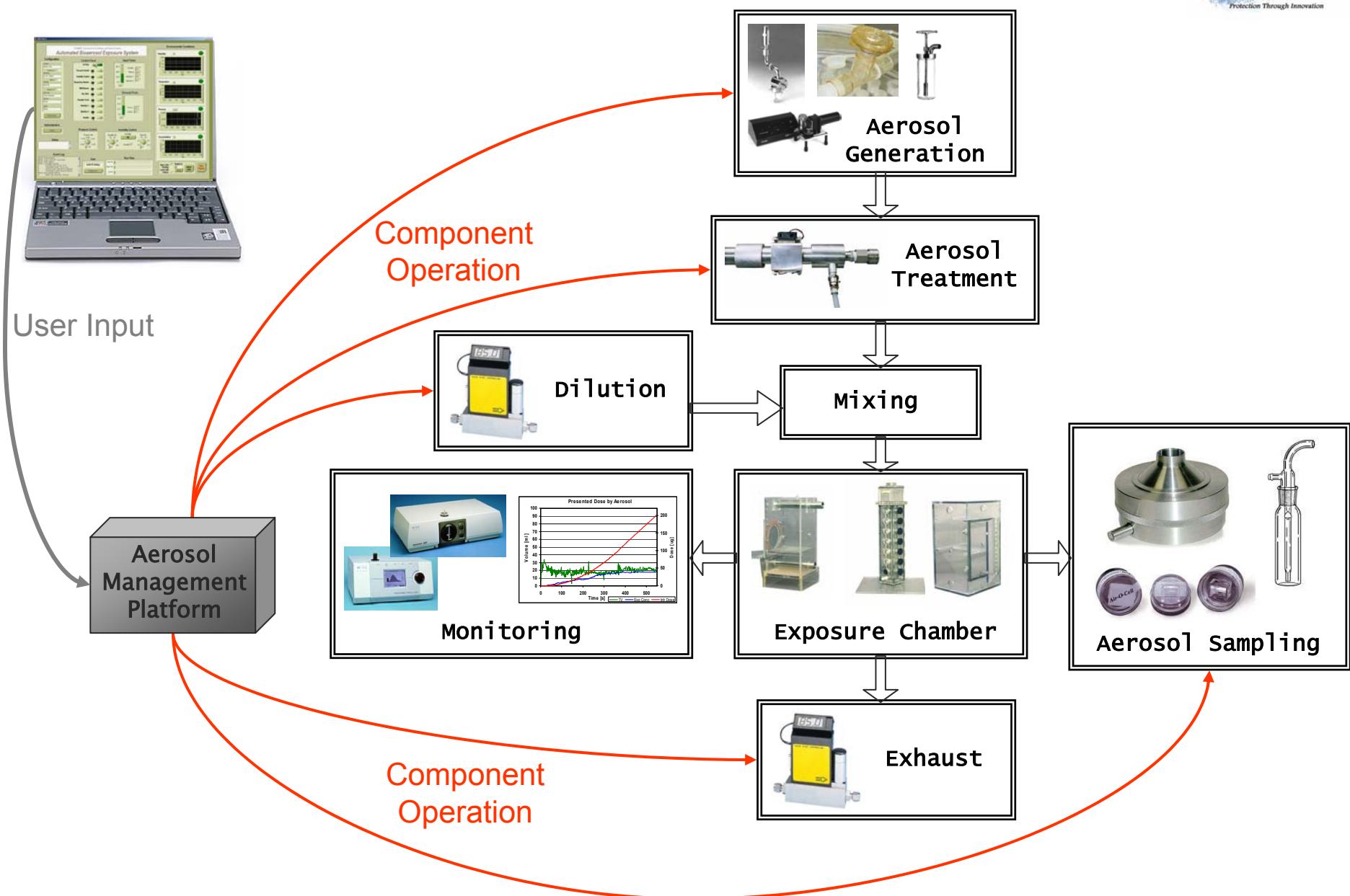


User Input



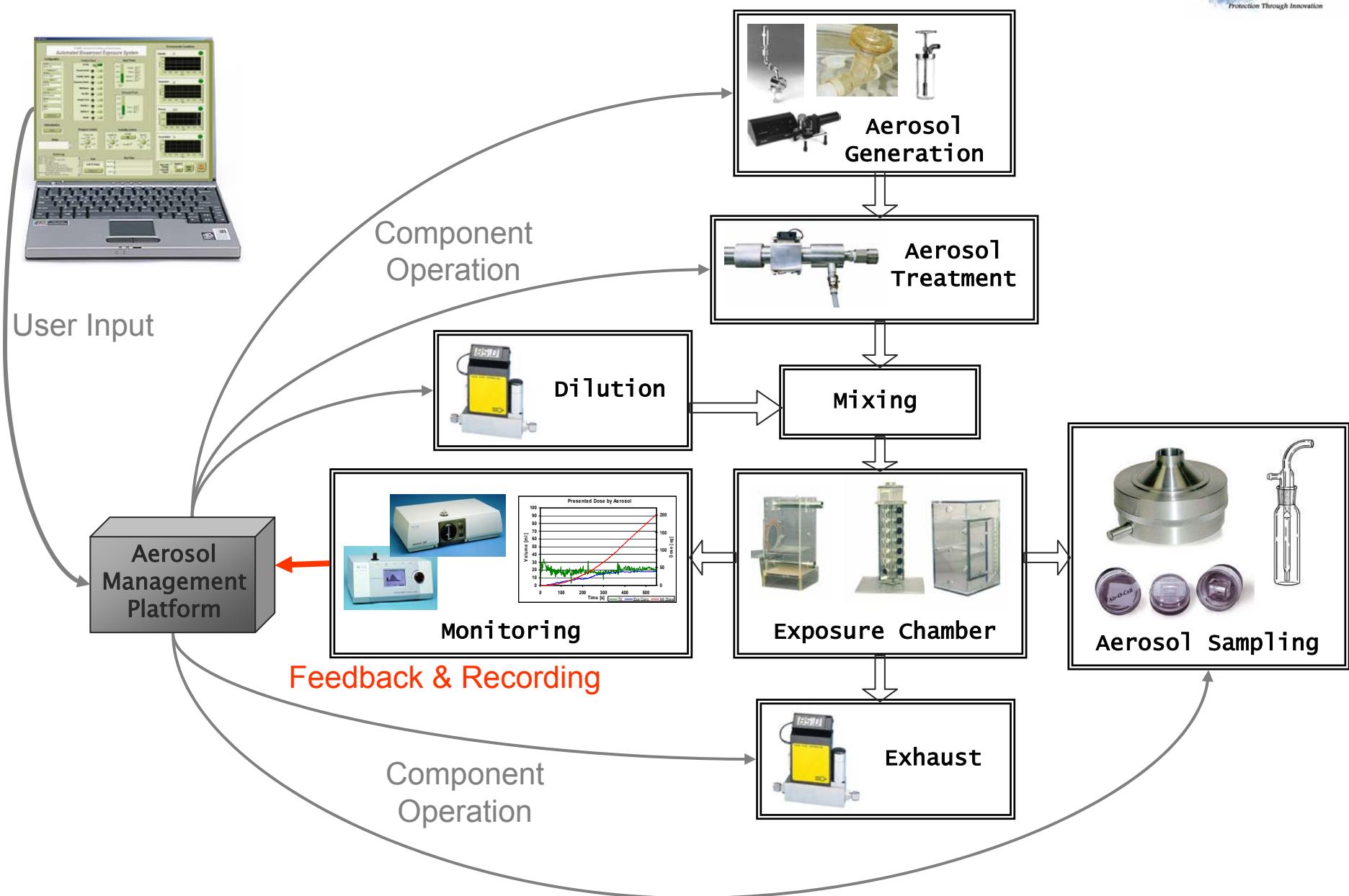


# Aerosol Management Platform Concept and Operation



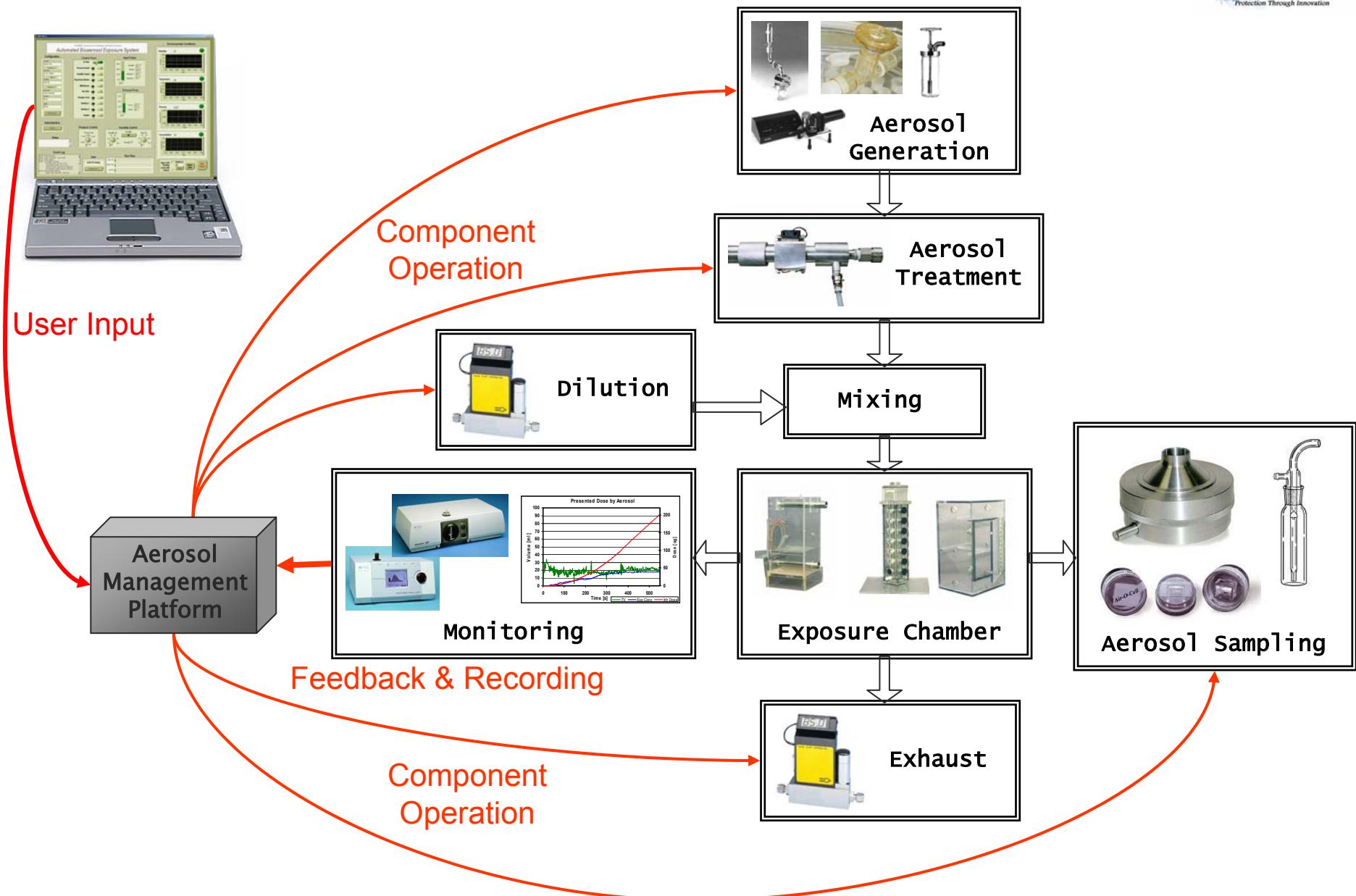


# Aerosol Management Platform Concept and Operation





# Aerosol Management Platform Concept and Operation

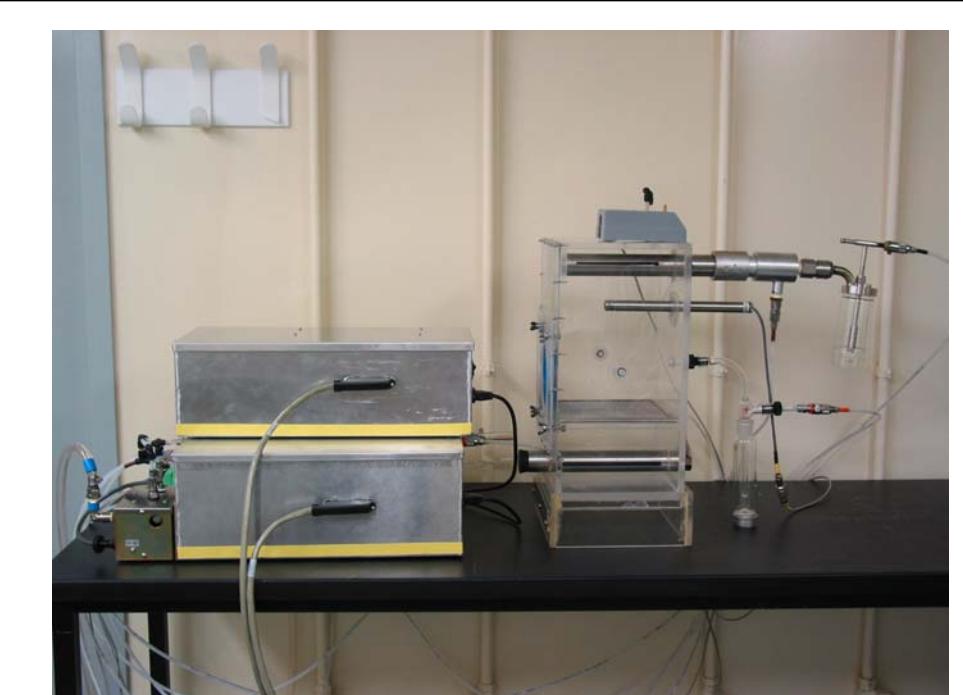




# Overview



Workstation

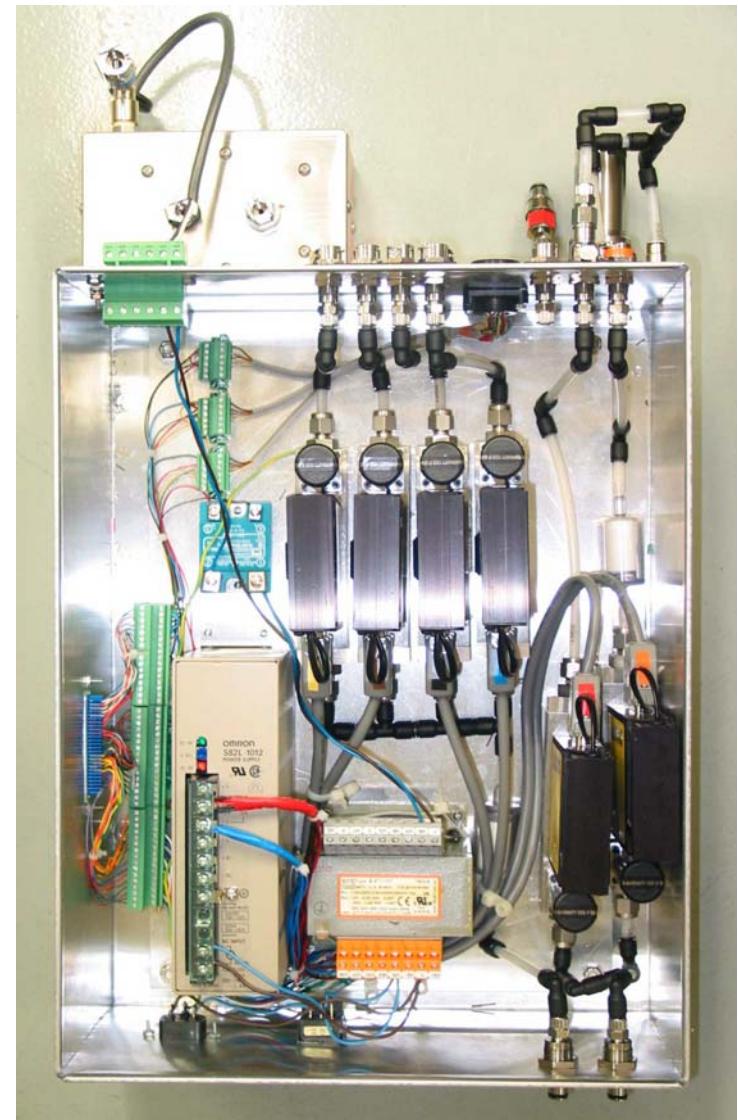


Containment



# System Hardware

- “Plug and Play” connections
- Electronic routing
- Power supplies
  - 12 Volt DC
  - Multi-tap AC transformer
- Mass flow controllers
- Relays
  - Electronic activation
  - Humidifier
- Multiple nebulizers or sampling devices





# System Software

- Custom programmed using LabVIEW
- Single user accountability (electronic signature)
- Modular for environmental controls
- User configurable for hardware and exposure control
- Programmatic controls to prevent errors





USAMRIID - Department of Aerobiology and Product Evaluation

# Automated Bioaerosol Exposure System

## Configuration

System  
Head Only  
System Q 16.0 lpm  
Nebulizer  
3 Jet Collision  
Neb Q 7.5 lpm  
Sampler  
AGI-30  
Sampler Q 6.0 lpm  
Exposure  
Dose Based  
Species  
NHP  
Agent  
Anthrax

[Reconfigure](#)

## Administrative

[Enter](#)

## Event Log

00:02:09 Display 55-55 Run 1 Started  
Run: 1  
AGI ID: 24  
Animal: xx  
Weight [g]: 5800  
Sampler Vol [ml]: 10  
Neb Conc: 3.000000E+8  
Spray Factor: 7.000000E-7  
Dose: 3.000000E+6  
Save Period: 00:05  
00:01:27 Run Parameters Entered  
00:01:11 Humidity Setpoint Changed to: 60 %  
00:01:07 Humidity Setpoint Changed to: 55 %

## Control Panel

Air Flow  
Pressure Control  
Humidity Control  
Nebulizer 1  
Sampler  
Run Start  
Nebulizer 2  
Respiratory Monitor  
DBE Balance

## Pressure Control



## User

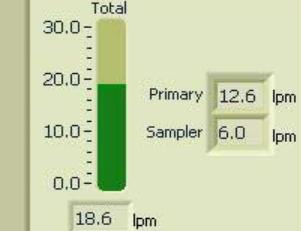
Justin M. Hartings

[E-Signature](#)

## Input Flows



## Exhaust Flows



## Humidity Control

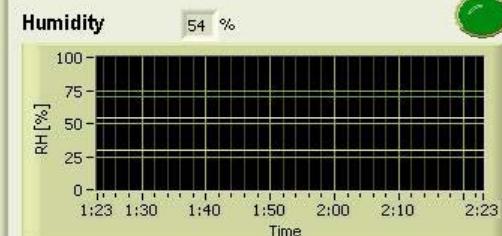


## Run Files

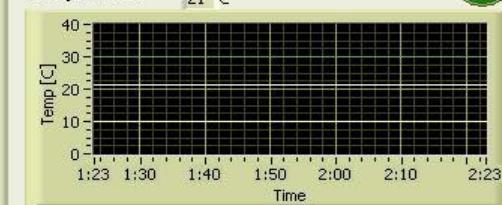
Data File C:\Program Files\National Instruments\Hartings\Display\55-55\Run 1\Display 55-55 Run 1 Data  
Report File C:\Program Files\National Instruments\Hartings\Display\55-55\Run 1\Display 55-55 Run 1 Report.html  
Log File C:\Program Files\National Instruments\Hartings\Display\55-55\Run 1\Display 55-55 Run 1 Log

## Environmental Conditions

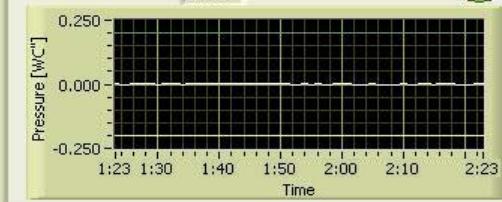
### Humidity



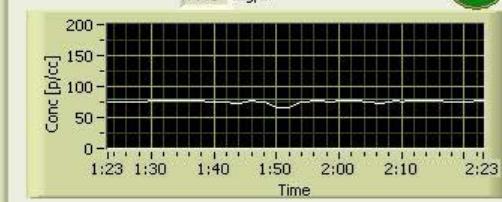
### Temperature



### Pressure



### Concentration



Upper Limit  
Reading  
Lower Limit  
Failures

Sample(s)  
1  
Reset

Adjust  
Limits

Stop  
Program



# System Event Log

- Time stamped event recording
  - Computer initiated
  - User initiated
- Single user accountability
- Quality management tool
- SOP compliance verification
- Troubleshooting
- FDA electronic filing

00:13:50	Concentration = 0 ug/L out of limits
	Humidity Limits: 30 % to 70 %
	Temperature Limits: 10 C to 30 C
	Pressure Limits: -0.200 WC" to 0.200 WC"
	Concentration Limits: 200 ug/L to 300 ug/L
00:13:48	Environmental limits set
00:11:54	Sampler On
00:11:39	Pressure Normal
00:11:38	Press = -0.230 WC" out of limits
00:11:37	Nebulizer 1 On
00:11:33	Nebulizer 1 Off
00:11:16	Pressure Normal
00:11:15	Press = -0.239 WC" out of limits
00:11:13	Nebulizer 1 On
00:11:04	Nebulizer 1 Off
00:10:56	Pressure Normal
00:10:54	Press = -0.230 WC" out of limits
00:10:53	Nebulizer 1 On
00:10:38	Nebulizer 1 Off
00:10:22	Humidity Normal
00:10:10	Pressure Normal
00:10:08	Press = -0.241 WC" out of limits
00:10:07	Nebulizer 1 On
00:08:05	RH = 30 % out of limits
00:04:14	Humidity Normal
00:03:05	Airflow Started
	Protocol Number: F03-11
	Principal Investigator: Pitt
	AED Number: 2003-
	System Location: 119
	Hoodline ID: 4
	Generator Number: G
00:02:22	Administrative Information Entered
	System Type: Head Only - 16.0 lpm
	Nebulizer Type: 3 Jet Collison - 7.5 lpm
	Sampler Type: AGI-30 - 6.0 lpm
	Exposure: Time Calculated
	Animal Species: NHP
	Agent: Plague
00:00:50	System Configuration Entered
00:00:06	Yellow System Selected
	Network Drive N:\ Found
00:00:00	E-Signature: Justin M. Hartings
	User Login
	Wednesday, October 29, 2003
	08:38:06 AM Eastern Standard Time



# Data File

- Stand alone record of exposure
- Administrative data
- Flow and environmental data
- Part 11 compliant file system
- Automatic file structure development
  - Investigators
  - Animal use protocols
  - Exposure schedule



# Exposure Data File



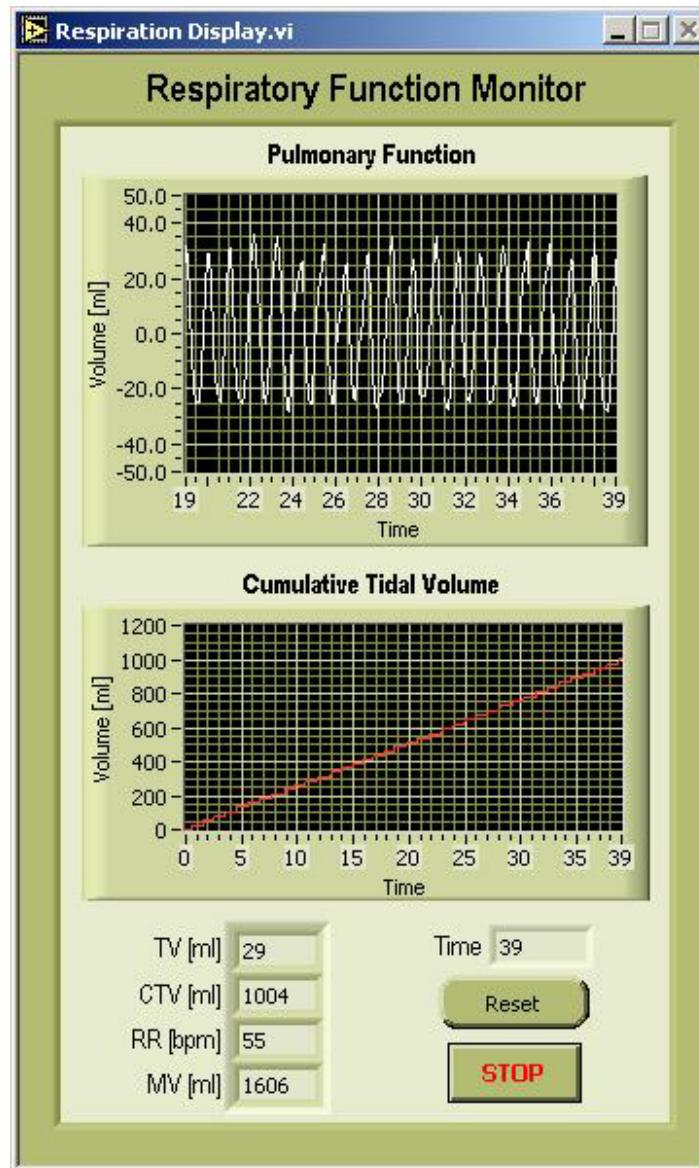
Justin M. Hartings														
Data File Started														
Wednesday, October 29, 2003														
11:41:25 AM Eastern Standard Time														
System: Head Only	Protocol:				Run Number: 6		Neb Conc: 4.00E+06		cfu/ml					
System Flow [lpm]: 16	Principal Investigator:				AGI Number: AA65		Spray Factor: 1.20E-06							
Nebulizer: 3 Jet Collison	AED Number:	2003-404			Sampler Vol [ml]: 10		Minute Vol [ml]: 552							
Nebulizer Flow [lpm]: 7.5	System Location:	119			Save Period: 0:05		Guyton Used: No							
Sampler: AGI-30	Hoodline ID:	4			Animal Number: 59-25		Required Dose: 2.57E+04		cfu					
Sampler Flow [lpm]: 6	Generator Number:	G			Weight [g]: 7500									
Exposure: Time Calculated														
Animal Species: NHP														
Agent: Bacterial														
Time [sec]	RH [%]	Temp [C]	Press [WC"]	Conc [ug/L]	Hum Q [lpm]	2nd Q [lpm]	Neb 1 Q [lpm]	Neb 2 Q [lpm]	Pri Exh Q [lpm]	Sampler Q [lpm]	Sampler Q [lpm]	Tot In Q [lpm]	Tot Exh Q [lpm]	
5.268	21.299	26.648	0.153	0.069	0.104	8.434	7.786	0.17	10.17	3.808	3.808	16.493	13.978	
10.265	22.62	26.648	0.017	0.069	0.104	8.5	7.467	0.148	10.039	5.687	5.687	16.219	15.725	
15.272	25.952	26.685	-0.005	0.069	0.071	8.478	7.445	0.137	10.028	5.774	5.774	16.131	15.802	
20.27	30.09	26.685	0.033	0.215	0.093	8.511	7.456	0.148	10.039	5.84	5.84	16.208	15.879	
25.267	33.279	26.685	0.057	0.069	0.104	8.511	7.5	0.148	10.006	5.862	5.862	16.263	15.868	
30.264	37.893	26.685	0.024	0.069	0.082	8.489	7.5	0.137	10.028	5.884	5.884	16.208	15.912	
35.271	40.679	26.721	-0.003	0.069	0.093	8.533	7.5	0.148	10.039	5.895	5.895	16.274	15.934	
40.268	43.718	26.685	-0.047	0.655	0.082	8.511	7.489	0.126	10.05	5.906	5.906	16.208	15.956	
45.265	45.513	26.721	0.05	6.368	0.104	8.5	7.522	0.137	10.039	5.917	5.917	16.263	15.956	
50.263	47.71	26.721	-0.019	25.42	0.093	8.5	7.511	0.159	10.017	5.917	5.917	16.263	15.934	
55.27	49.541	26.721	-0.006	60.146	0.104	8.5	7.511	0.137	10.006	5.928	5.928	16.252	15.934	
60.267	50.679	26.721	-0.025	98.975	0.104	8.511	7.511	0.137	10.017	5.917	5.917	16.263	15.934	
580.265	57.783	26.978	0.026	188.203	0.082	8.511	7.511	0.159	10.028	5.972	5.972	16.263	16	
585.272	58.223	26.978	-0.012	188.35	0.082	8.5	7.522	0.159	10.039	5.983	5.983	16.263	16.022	
590.269	58.333	26.941	-0.002	189.229	0.093	8.544	7.522	0.159	10.028	5.972	5.972	16.318	16	
595.266	58.333	26.978	0.026	191.426	0.082	8.489	7.533	0.159	10.006	5.983	5.983	16.263	15.989	
600.264	58.369	26.978	0.05	192.012	0.104	8.511	7.533	0.159	10.006	5.972	5.972	16.307	15.978	
603.268	58.149	26.978	0.027	190.84	0.082	8.5	7.522	0.148	10.028	5.972	5.972	16.252	16	
E-Signature: Justin M. Hartings														
Original Data														
Wednesday, October 29, 2003														
11:56:54 AM Eastern Standard Time														



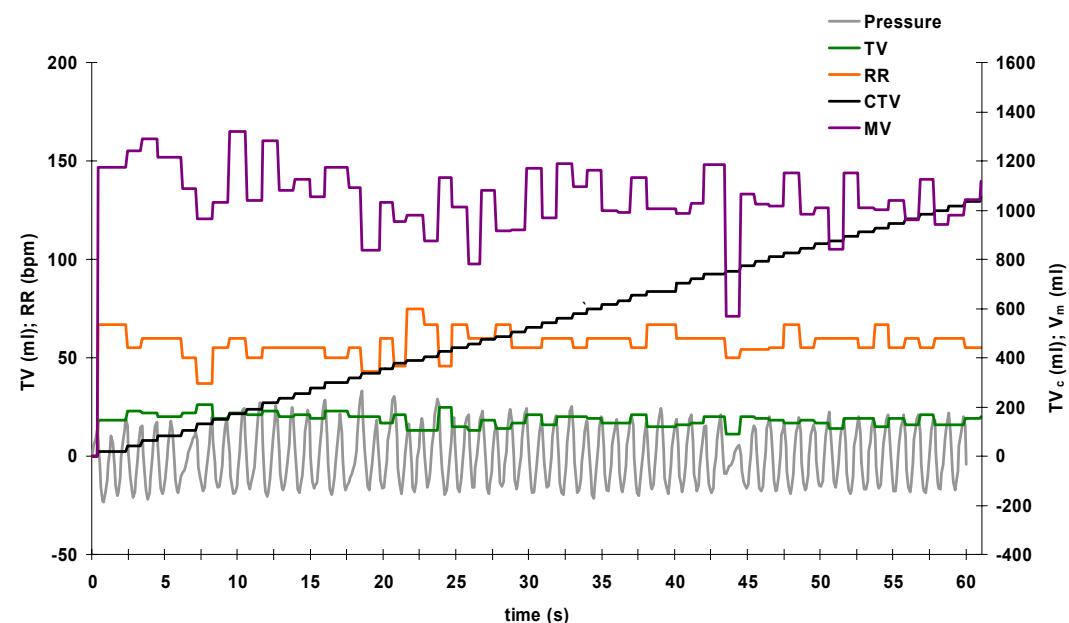
# Respiratory Monitoring Module

- Controlled input and exhaust creates a sealed dynamic chamber
- For head-only exposures, animal respiratory tract functions as part of the chamber
- Animal respiration changes chamber volume
- Volume change produces pressure change detected by system hardware
- Pressure signal serves dual purpose
  - DC component used for system balancing
  - AC component used for respiratory monitoring



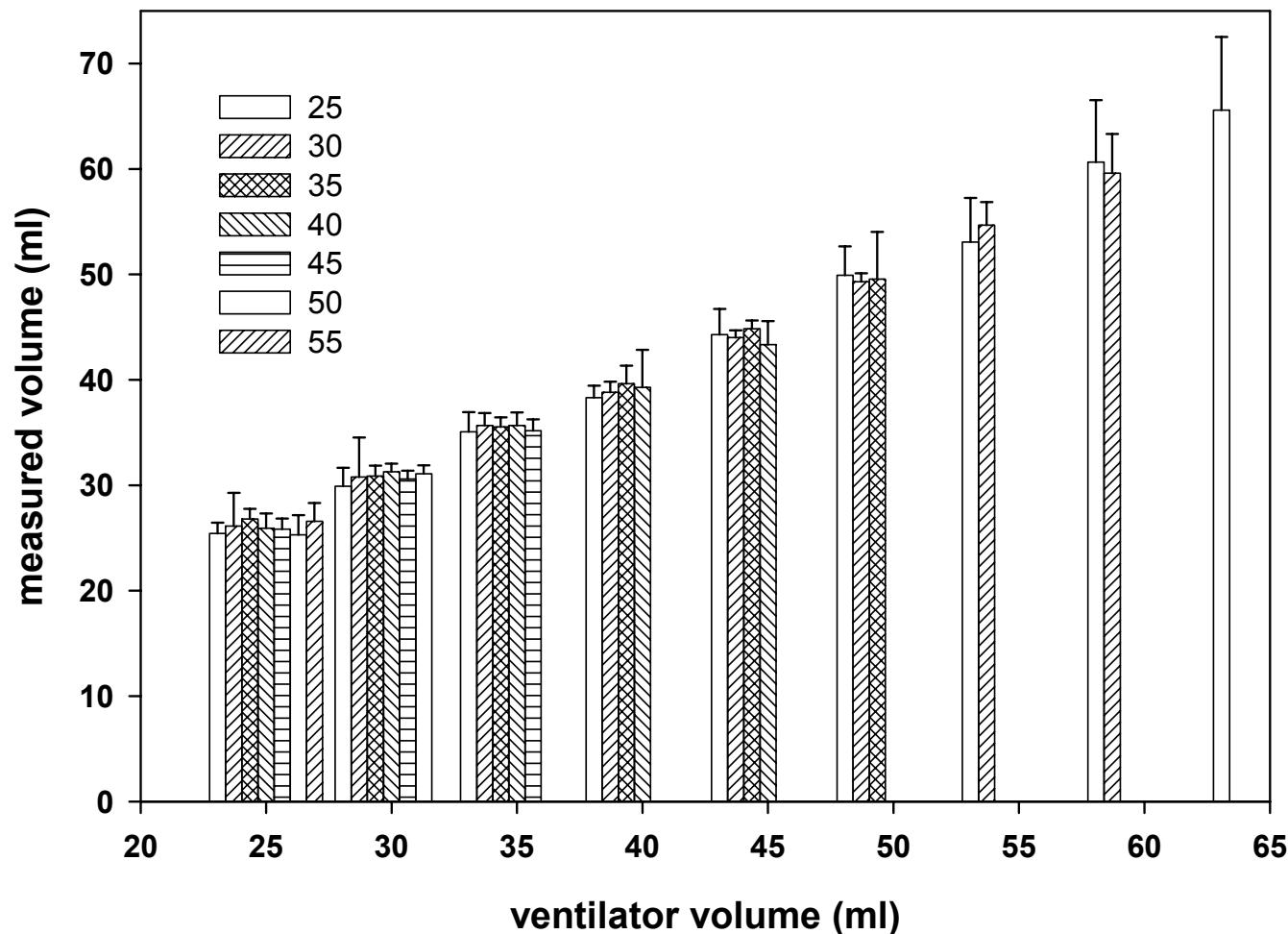


# Respiration

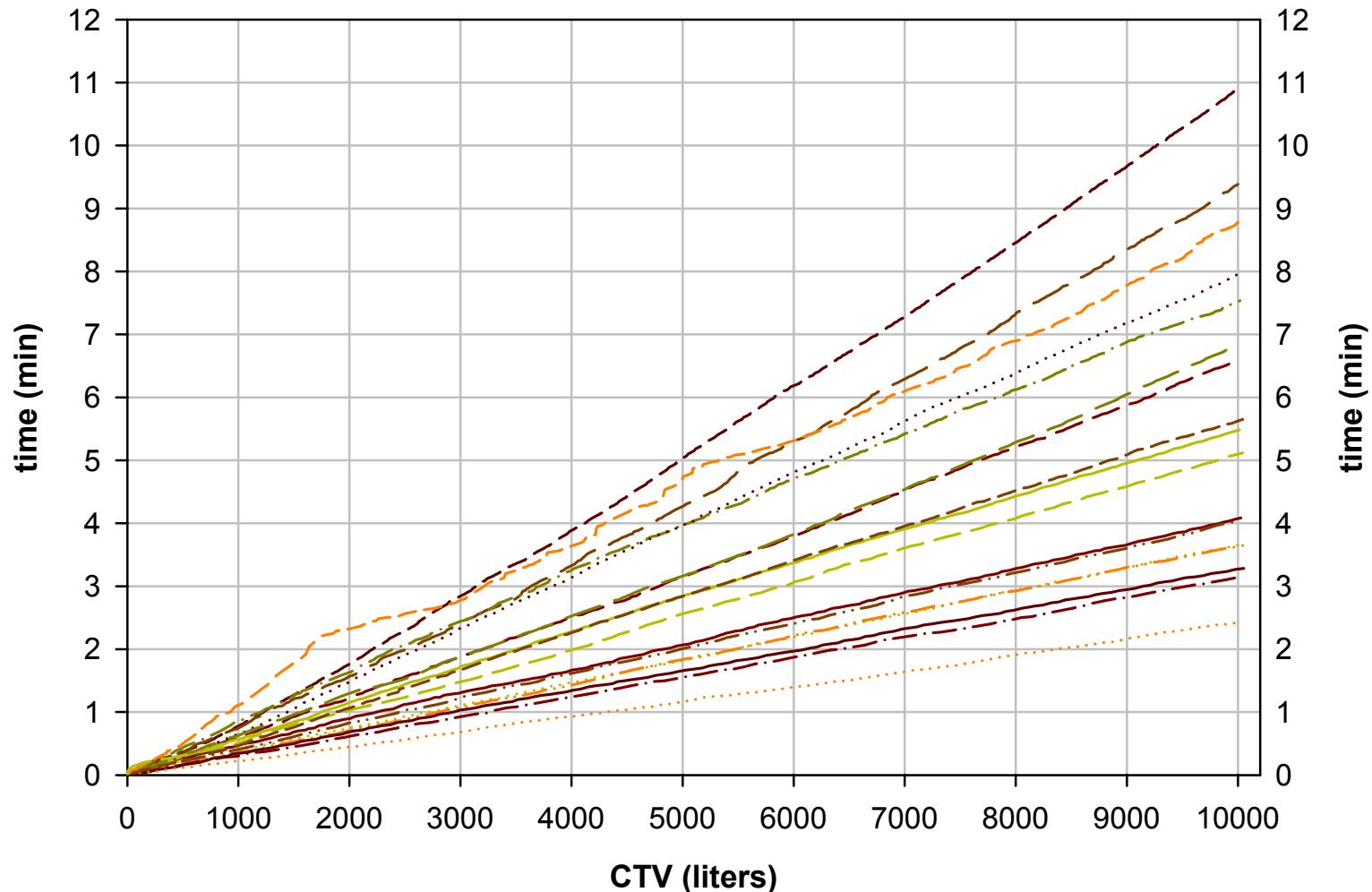




# Respiratory Module Calibration



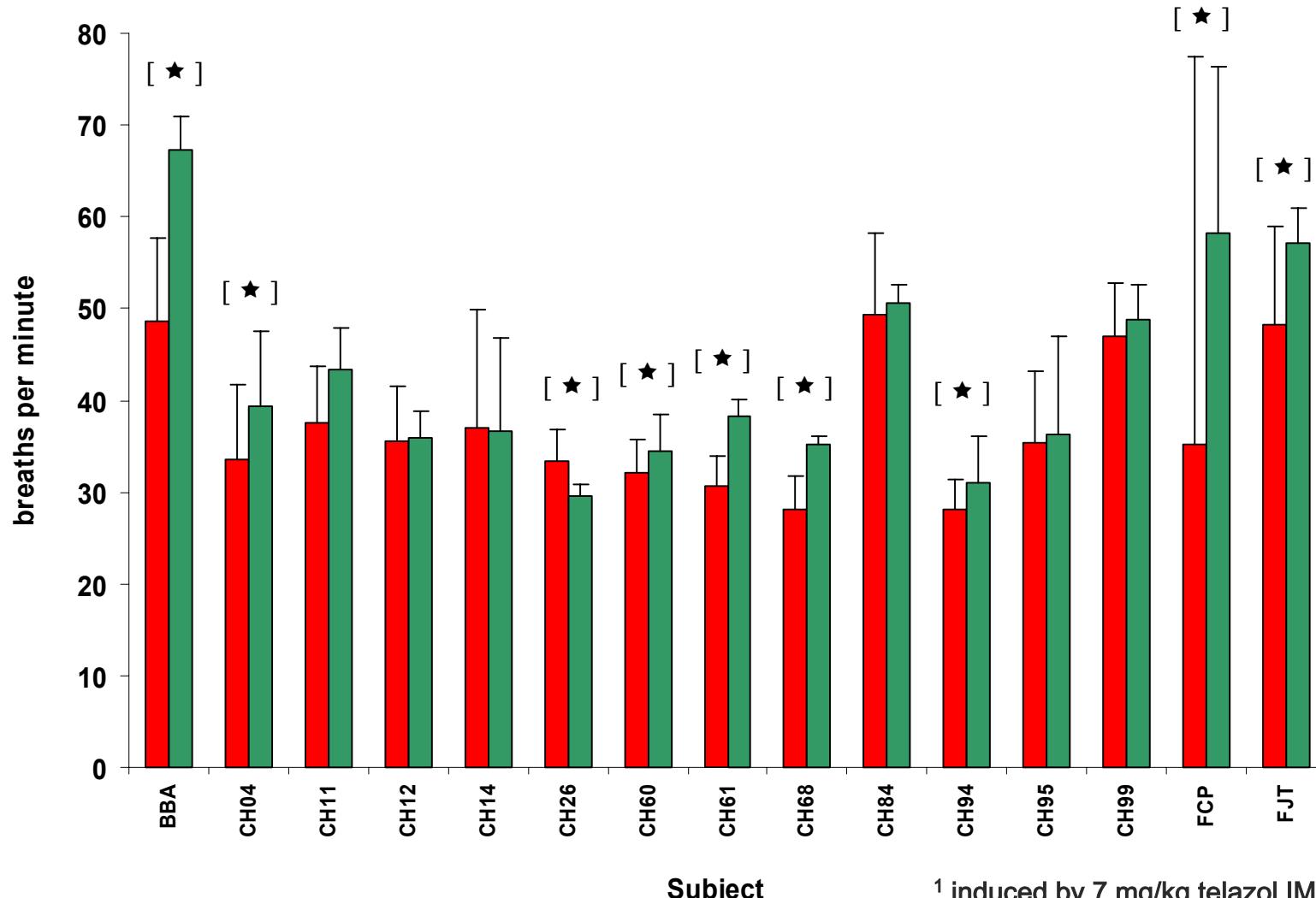
From Hartings and Roy, *In Press*



Cumulative tidal volumes (CTV) of sham-exposed anesthetized Rhesus macaques ( $n=15$ ) utilizing the dosimetry function of the ABES. An arbitrary limit of 10,000 ml was preset to demonstrate breathing rate and depth differential in the primates under study.



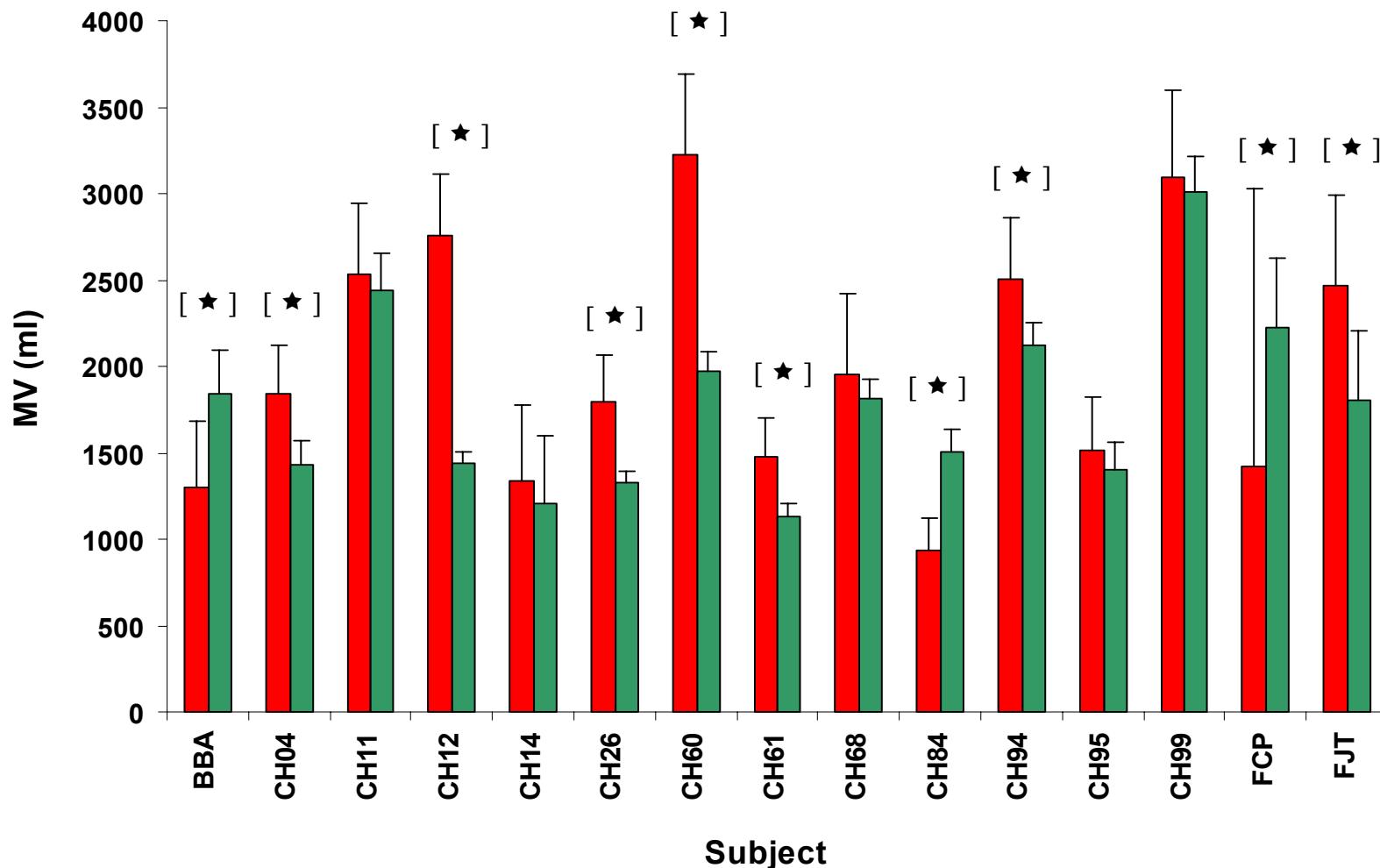
Mean *breaths per minute* of anesthetized<sup>1</sup> Rhesus macaques (n=15) using either whole-body plethysmography (red) or the ABES (green). Error bars represent standard deviation; significance at  $p<0.01$  denoted by asterisk and bracket (9/15).



<sup>1</sup> induced by 7 mg/kg telazol IM as needed



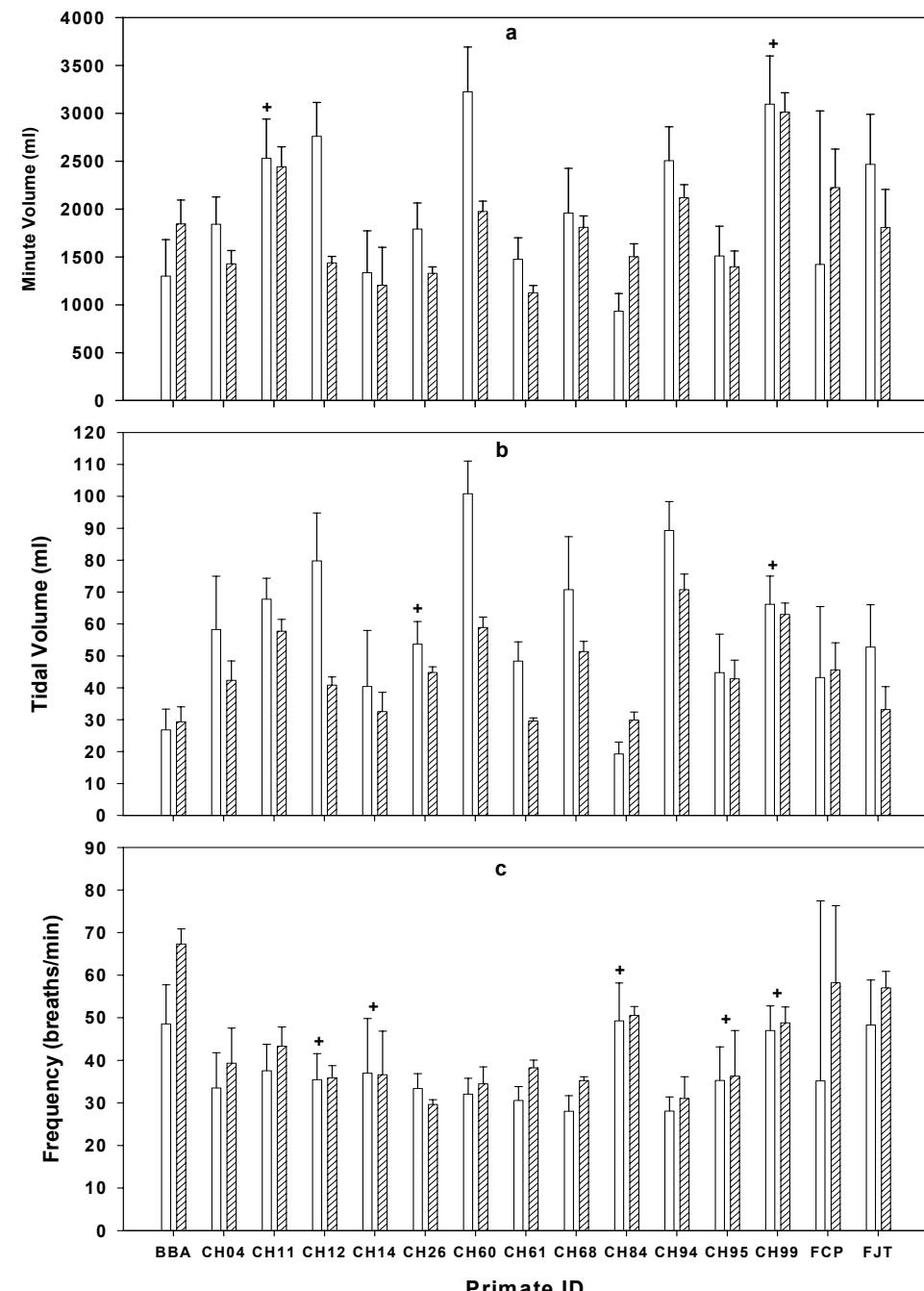
Mean *minute volume* of anesthetized<sup>1</sup> Rhesus macaques (n=15) using either whole-body plethysmography (red) or the ABES (green). Error bars represent standard deviation; significance at  $p<0.01$  denoted by asterisk and bracket (10/15).



<sup>1</sup> induced by 7 mg/kg telazol IM as needed



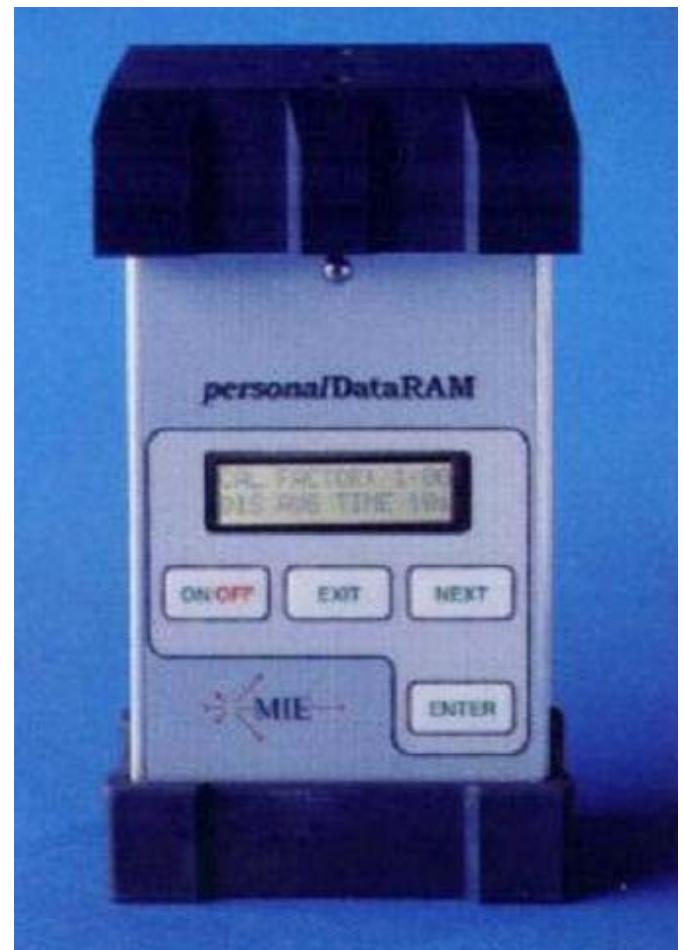
Comparison of minute volume (a), tidal volume (b), and respiratory frequency (c) measurements as determined by ABES and WBP in sham-exposed NHPs. Error bars represent standard deviation. Analysis using the Wilcoxon rank-sum showing no difference between methods is denoted by + at  $p<0.05$ .





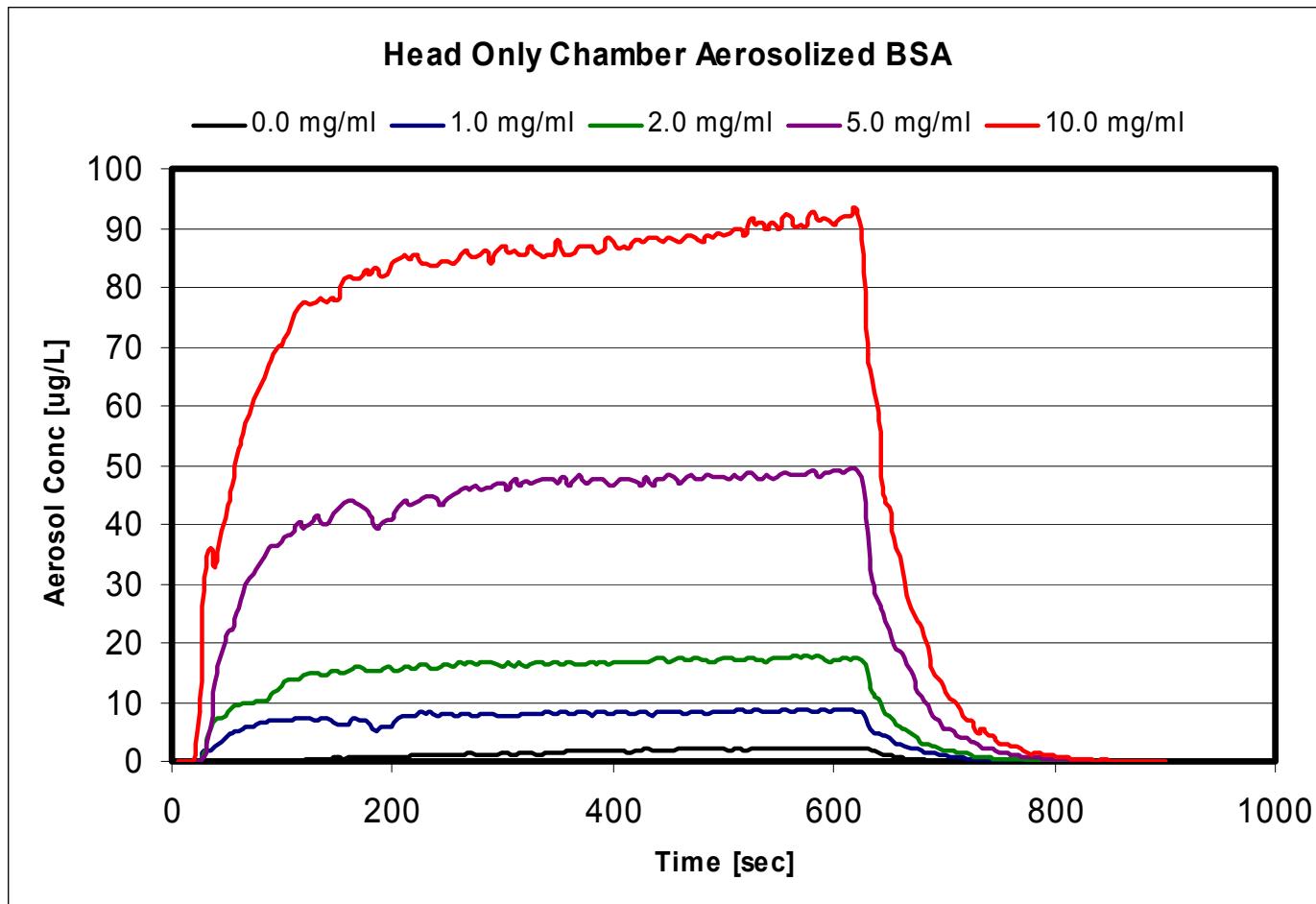
# Aerosol Concentration

- Passive air sampling
- Real-time monitoring
- Optical scattering
- Commonly used in personal monitoring
- 0.001 to 400 mg/m<sup>3</sup> autoranging
- Digital or analog output
- Ideal for Automated System





# Concentration Monitoring





# Real-Time Dosing for Toxins

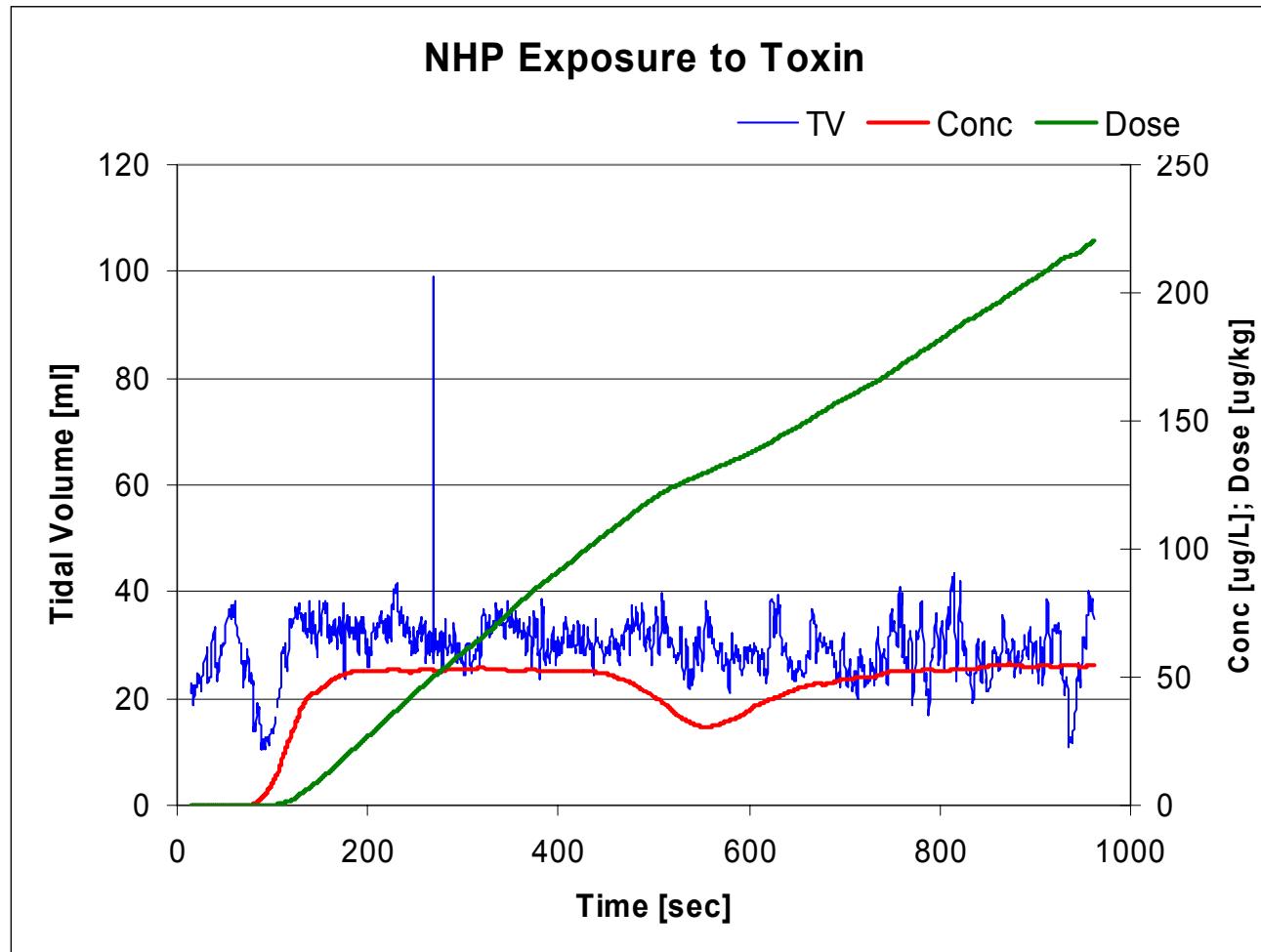
- Combine DataRAM results with respiratory measurement
- Calculate discrete dose in real-time for each breath

$$D = \sum_{n=1}^m R_n \times C_n$$

- Automatically terminate exposure when requisite dose is achieved
- NHP exposure to toxin
  - Target dose of 220 µg/kg
  - Collect with AGI to compare dose results



# Real-Time Dose Control



AGI Results:  $D = 210 \pm 20 \mu\text{g}/\text{kg}$